Mobile Broadband Spectrum Considerations

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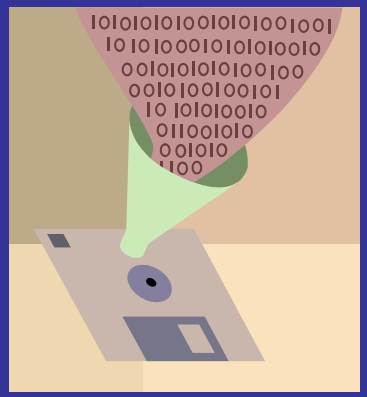
Data Explosion

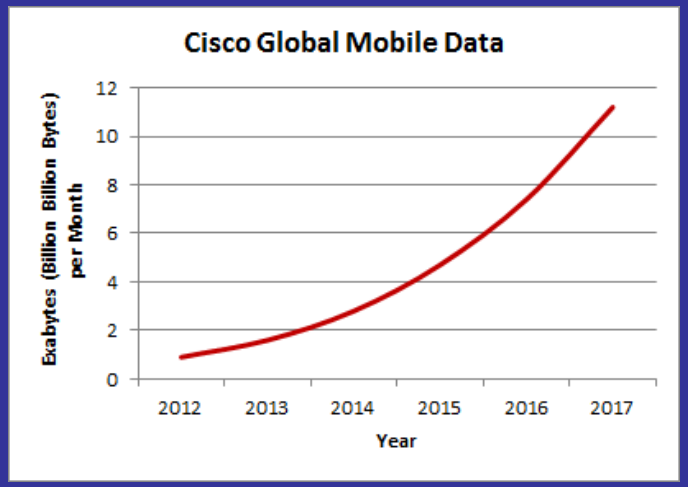
Faster Networks

Better Smartphones,
Tablets, Netbooks, …

Mass Adoption



More Applications

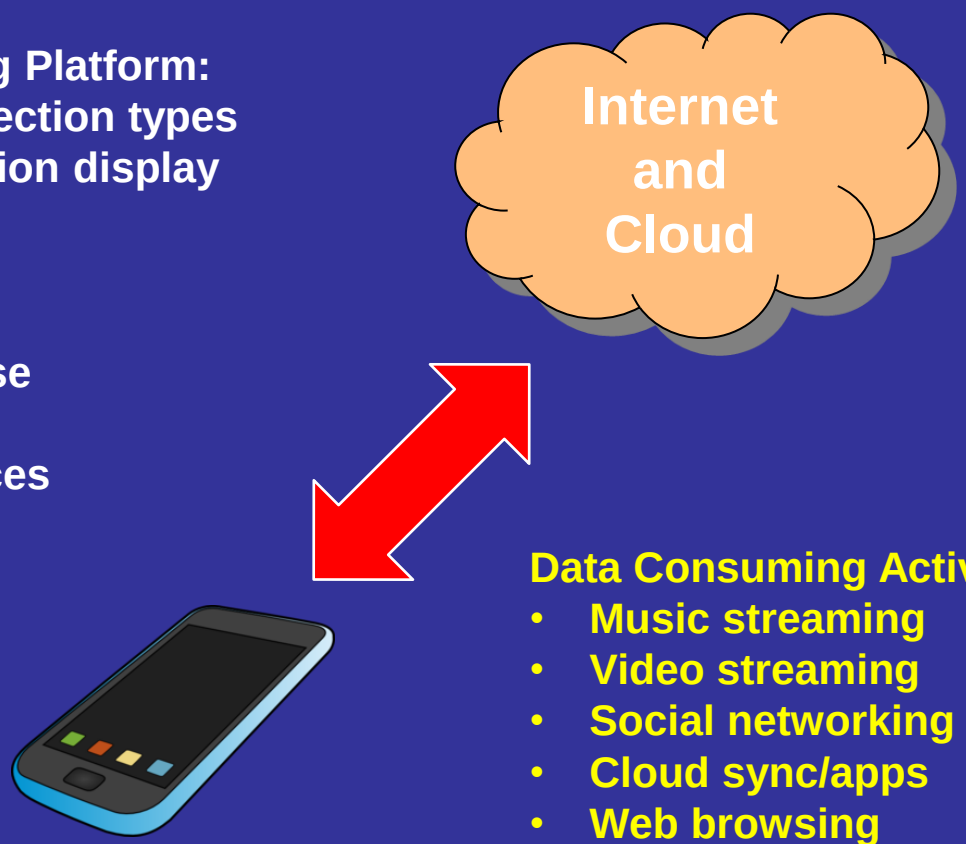


Cisco
Global

Data Drivers

Modern Mobile Computing Platform:

- **Multiple wireless connection types**
- **Extremely high-resolution display**
- **Application platform**
- **HTML 5**
- **Multimedia**
- **Sync to cloud/enterprise**
- **Navigation**
- **Hotspot for other devices**



Data Consuming Activities:

- **Music streaming**
- **Video streaming**
- **Social networking**
- **Cloud sync/apps**
- **Web browsing**
- **Content downloading**

Data Consumption of Typical Applications

Application	Throughput (Mbps)	MByte/hour	Hrs./day	GB/month
Audio or Music	0.1	58	0.5	0.9
			1.0	1.7
			2.0	3.5
			4.0	6.9
Small Screen Video (e.g., Feature Phone)	0.2	90	0.5	1.4
			1.0	2.7
			2.0	5.4
			4.0	10.8
Medium Screen Video (e.g., Smartphone Full-Screen Video)	1.0	450	0.5	6.8
			1.0	13.5
			2.0	27.0
			4.0	54.0
Larger Screen Video (e.g., Netflix Lower Def. on Tablet or Laptop)	2.0	900	0.5	13.5
			1.0	27.0
			2.0	54.0
			4.0	108.0
Larger Screen Video (e.g., Netflix Higher Def. on Laptop)	4.0	1800	0.5	27.0
			1.0	54.0
			2.0	108.0
			4.0	216.0
Video applications: telemedicine, education, social networking, entertainment.				

Small number of users with high-bandwidth applications can consume network capacity.

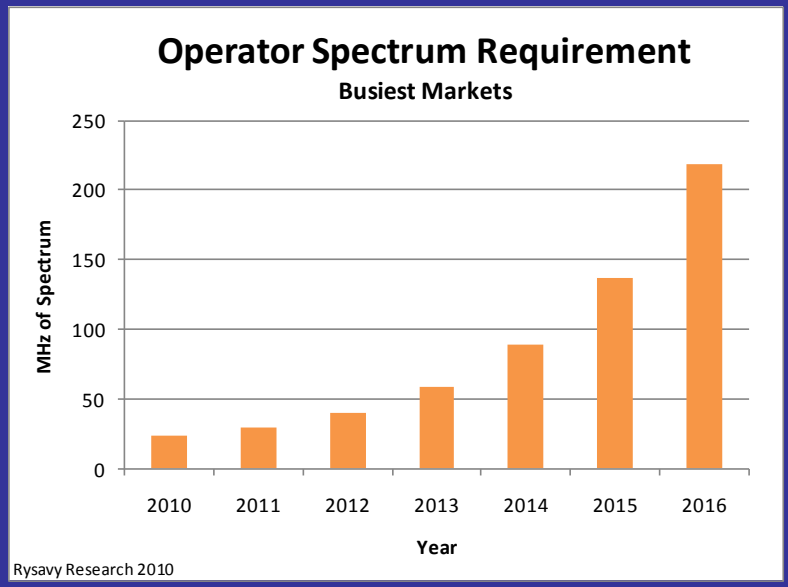
So, Is There a Crunch?

- Not if you don't mind high prices
- Possibly not if you don't stream, don't use the cloud, and don't do social networking
- If no, why are operators going to such extraordinary lengths to obtain more spectrum?
- In other words, yes
- Confirmed by FCC and Rysavy analytical methods

Rysavy Model for Spectrum Demand

- Variables, current and future:
  - Number of subscribers
  - Data usage per month per device type
  - Penetration of different devices types
  - Number of cell sites
  - Spectral efficiency of technologies
  - Busy hour considerations
  - Busiest cell considerations
- Similar analysis for voice support

➢ Calculate amount of needed spectrum



Originally published in "Mobile Broadband Capacity Constraints And the Need for Optimization," February 24, 2010.

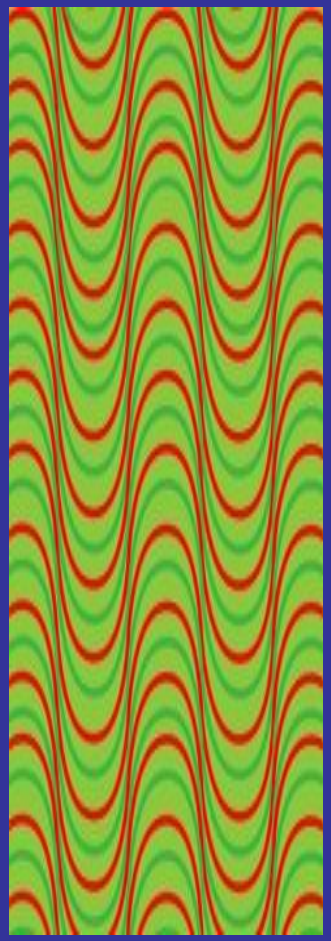
http://www.rysavy.com/Articles/2010_02_Rysavy_Mobile_Broadband_Capacity_Constraints.pdf

Capacity: Pursuing All Options

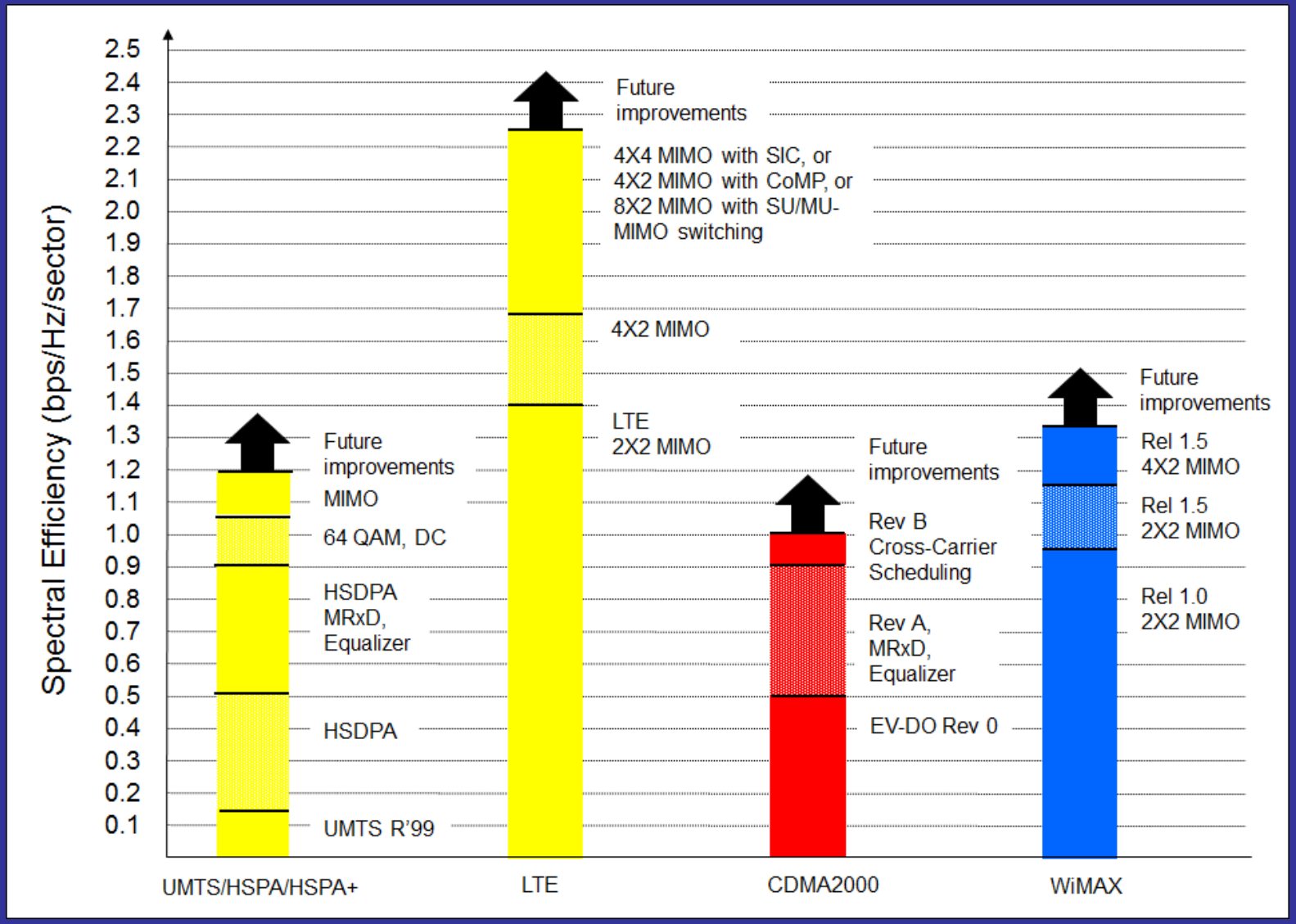
Method	Occurring	Comments
More efficient technology	Yes	LTE and LTE-Advanced.
Smart antennas	Yes	Major emphasis in LTE and LTE-Advanced.
Infrastructure investment	Yes	US carriers investing huge sums.
Wi-Fi offload	Yes	US carriers pursuing aggressively.
Small cells (and heterogeneous networks)	Yes	Carriers have announced plans. Major emphasis in 3GPP work.
Making best use of available spectrum	Yes	Refarming. Spectrum aggregation in LTE-Advanced.
New cleared spectrum	Slowly	Various initiatives underway but major challenges exist.
Spectrum sharing	Not yet	Industry and government evaluating, complexities.

Efficient Use of Spectrum

- Multiple measures:
  1. Spectral efficiency – bps/Hz
  2. Capacity - Gbps/sq. km. for specified spectrum
  3. Users supported for given minutes/data
- Hugely efficient:
  - LTE/LTE-Advanced in dense deployments
  - Wi-Fi in current 2.4 and 5 GHz bands
- Inefficient:
  - White-space networks (low frequency reuse)
  - Certain government applications (low bps/Hz, large coverage areas)
- Should all spectrum allocations consider efficiency?
  - Not always applicable (e.g., radar)
  - Provides impetus for optimal spectrum use



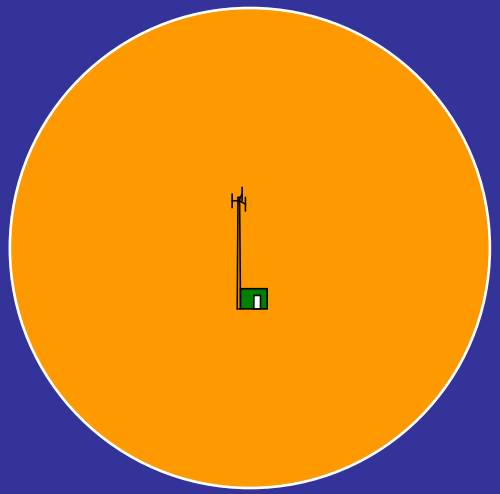
Comparison of Downlink Spectral Efficiency



LTE the most efficient technology ever developed.

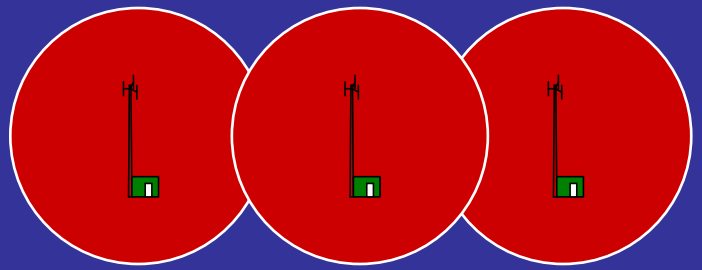
Source: Rysavy Research white paper for 4G Americas.

Spectrum Deployment Considerations



Lower frequencies:

- Longer propagation
- Fewer cells required for coverage
- Better in-building penetration



Higher frequencies:

- Shorter propagation
- More cells required for coverage
- **BUT higher capacity network**

Spectral efficiency (bandwidth in spectrum) is equivalent.
Ideal: blend of high/low spectrum.

Sharing

- When does sharing make sense?
- Lightly used resources
- Well-defined requirements for all entities
- Not necessarily most efficient for all cases

Many Types of Sharing

- Goal: improve spectrum utilization in frequency, location, and time

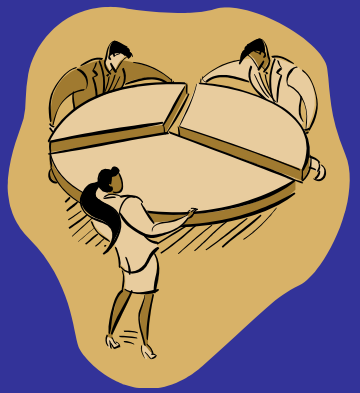
1. Simplest: geographic exclusion zones

   E.g., Advanced Wireless Services (AWS) must protect from interference DoD facilities in 1710-1755 MHz

2. More complex: dynamic spectrum access

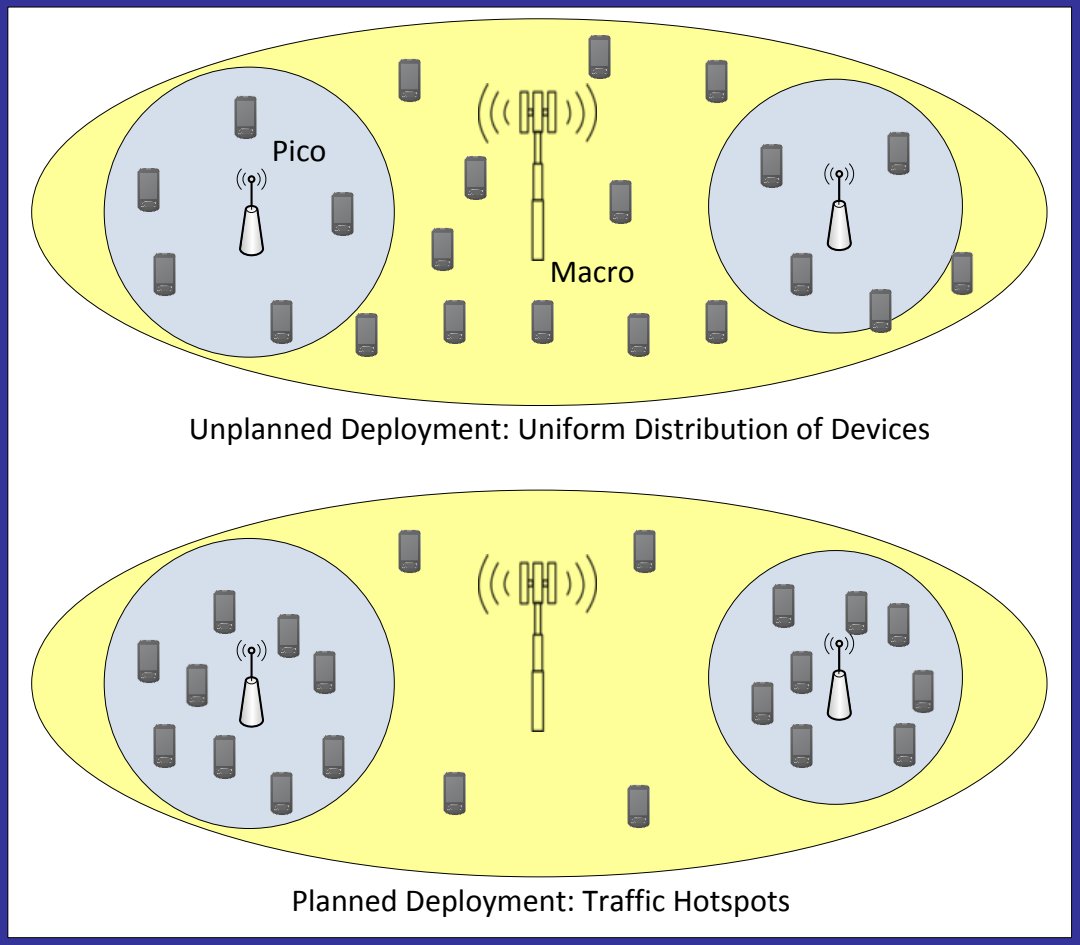
   Cognitive radio

   Frequency/spectrum coordination



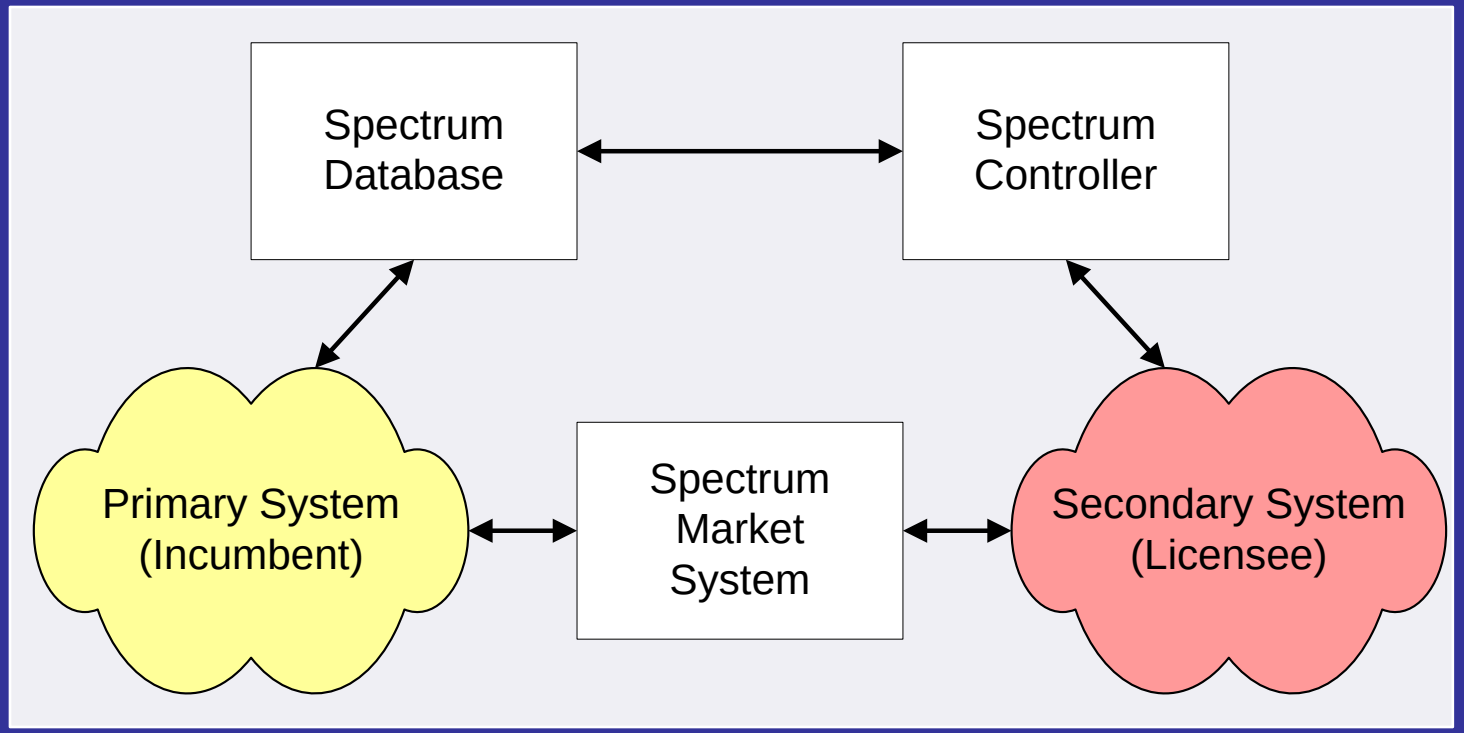
Sharing in LTE Heterogeneous Networks

Spectrum sharing between macro and pico – extremely complex
Requires enhanced Inter-Cell Interference Coordination (eICIC)



Sharing: Long-Term Process

- Negotiation and stipulation of access rights
- Design of frequency coordination systems
- Development of standards
- Certification and enforcement



Sharing – How to Succeed

- Have realistic expectations
  - Carriers need predictable resources
  - Medium access for wireless already complex
  - Access across disparate systems increases complexity
- Don’t use worst-case assumptions for protection/exclusion zones
  - Otherwise available coverage areas are not useful
- Simplify to two tiers: incumbent, licensee
  - Unlicensed use increases complexity
  - Consider for future
- Limit number of bands
  - Huge learning curve involved, need to learn
  - Small cells may represent greatest opportunity

dawn of the mobile broadband era

- Mobile broadband transforming the world
- Spectrum crunch is real
- Spectrum sharing will be long and involved